DOPPLER VELOCITY MEASUREMENTS MADE WITH A SCANNING PHOTOELECTRIC MAGNETOGRAPH

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(Received 19 August, 1994; in revised form 20 April, 1995)

Abstract. We discuss the problems connected with the measurements and evaluation of line-of-sight velocities, obtained with a scanning photoelectric magnetograph using a line-shifter with enhanced sensitivity. We bring arguments for the validity of the results of our photoelectric Doppler velocity recordings. We have found a network of cellularly shaped patterns in the distribution of photoelectrically measured line-of-sight motions, upflowing in the magnetically quiet (blue-shifted) and downflowing in magnetically active (red-shifted) areas of the photosphere, if the mean velocity level is estimated for a sufficiently large measured area. The features of both directions are mutually complementary. We demonstrate the effect of the shift of the reference zero velocity level on the topology of the line-of-sight velocity maps, and the dependence of this level on the size of the area from which it is estimated.

1. Introduction

Since the completion of the modernization of our classical-type scanning photoelectric magnetograph in 1990 (Klvaňa and Bumba, 1993a), we have measured the line-of-sight velocities in the solar photosphere systematically. So far, no systematic use of photoelectric measurements of the line-of-sight velocities, obtained with this type of magnetograph simultaneously with the values of the longitudinal component of the magnetic field for the investigation of photospheric motions has been made successfully. The reason is not just in the difficulties connected with the evaluation of photoelectric Doppler motion observations, made from Doppler shifts of the measured spectral line with the aid of a line-shifter, and in the fact that we cannot in practice get the absolute values of these velocities. We think that the main explanation is, above all, in the low sensitivity and speed with which the mechanical line-shifter reacts to impulses of the magnetograph. In our measurements, we have considerably improved the sensitivity as well as the speed of our Doppler velocity measurements electronically (Klvaňa and Bumba, 1994a).

We are convinced that a knowledge of photospheric motions is very important for understanding solar magnetic and other activities. We believe that classical magnetographs are still valuable instruments for studying the motion of solar matter, because they can relatively easily accumulate additional observational data concerning many different active regions by repeated measurements in a short time. Since we have succeeded in collecting relatively systematic observational material (more than 1000 sets of measurements in more than 150 active regions) during the
last five years, we want to discuss our line-of-sight velocity data and their validity from several points of view.

The first line-of-sight velocity maps we obtained demonstrated the many times discussed so-called blue and red shifts — systematic predominance of positive (toward the observer) motions in the quiet photosphere and negative (away from the observer) motions in regions occupied by magnetic fields. When we first presented them, we met with certain criticism, indicating the zero shift due to the contamination of our measurements by the Stokes parameter $V$ as the main source of our results. But we have also found a network of cellularly shaped patterns in the distribution of the motions studied, upflowing in the magnetically quiet and mostly downflowing in magnetically active areas. This was also our reason to study in more detail the Doppler velocity maps obtained and to investigate the effect of the shift of the reference zero velocity level on the topology of these maps.

2. Doppler Velocity Measurements at Ondřejov

Simultaneously with the line-of-sight component of the velocity of photospheric motions, obtained from the Doppler shift of this line (with enhanced sensitivity), the scanning photoelectric magnetograph (Klvaňa and Bumba, 1993a, 1994b; Klvaňa, Bumba, and Sobotka, 1994) measures the longitudinal component of the solar magnetic field and the intensity of light in the continuum, as well as in the center and both wings of the spectral line involved.

As concerns the solar image, the telescope has a focal length of 35 m (Ambrož et al., 1980). With the three available scanning modes (fast, normal, and fine-scale) we are able to achieve the following spatial resolutions: $6.4'' \times 9.6''$, $3.2'' \times 4.8''$, $1.6'' \times 2.4''$. The scanning time (which is important for taking into account the 5-min oscillations) is relatively short. For example, in the mostly-used normal mode, $7m40s$ are required for a full scan of an area of $300'' \times 200''$. The data may be improved by using several different filters, integrating the values received at the measured and neighbouring points in different directions and with different weights (Klvaňa, Bumba, and Sobotka, 1994).

Measurements are mostly made in the line Fe I 5253.47 Å with an effective Landé factor equal to 1.5 (which means weak splitting of the line in moderate magnetic fields). The Doppler measurements are made in the outer halves of the line wings in the fifth order of our spectrograph with a dispersion of 5.2 mm Å$^{-1}$ (Ambrož et al., 1980). This means that the shift of the zero-crossing wavelength of the Stokes parameter $V$ and its asymmetry play a minor role in our velocity measurements, if we, in addition, take into account the widths and arrangement of magnetograph’s slits (Klvaňa and Bumba, 1994a), the small widths of the spectrograph instrumental profile ($\leq 40$ mÅ) and its high spectral resolution of about 660000.